論文内容の要旨

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In the present study, the enriched finite element method (enriched FEM) and the conservative integral are used to analyze the intensity of singularity in dissimilar material joints. The study covers both two-dimensional and three-dimensional analyses.

For two-dimensional analysis, the enriched FEM was used to analyze the intensity of singularity in three-material joints with two-real and power-logarithmic singularities. Using this method, the intensity of singularities can be directly evaluated and a very refined mesh around the singular point is unnecessary.

For two-real singularities, the enriched FEM is modified applying a 2nd-order polynomial function to the shape function of the enriched element. Effects of changing enriched area and element size on accuracy of the intensity of singularity are investigated in details. The results confirm that the accuracy of the results can be improved. In addition, using 2nd-order polynomial function, the intensity of singularity is not a function of the enriched area. And then, the relationships between the intensity of singularity with model geometry, material combination and applied loading condition are investigated. Under shear-loading, the results for models with various lengths, L, and thicknesses, h, showed that the intensity of singularity increases when L/h increases. Furthermore, the growth rate of K_i decreases as the length increases, and the value of K_i approaches to the value corresponding to material combinations when the model is sufficiently long. The results for the models with various material combinations show that, the dimensionless intensities of the singularities decrease when a more compliant material, such as material 3, is used. In the case of two-real singularities, it is difficult to predict the failure of joints based on the intensities of the singularities, and additional information, such as the circumferential stress in the singular zone, should be considered. In addition, if one order of singularity is much smaller than the other order of singularity, the shape of the circumferential stress near the singular point is similar to the angular function of the larger order of singularity.

For power-logarithmic singularities, the enriched element formulation is developed, and the effect of changing mesh types and sizes is investigated in the same way as in 2-real singularities. In addition, the relationship between the intensity of singularity and model’s size is also studied. The results for various lengths and thicknesses showed that the intensities of singularity were constant with increasing lengths but the intensities of singularity decrease with decreasing thicknesses, and the intensities of singularity for various lengths and thicknesses could be well arranged by changing to be the form of dimensionless two-real singularities.

For three-dimensional analysis, the conservative integral formulation is developed for calculating the intensity of singularity in bi-material joints. This method has the advantage that it does not require special elements, very refined meshes around the singular point is unnecessary and complex external boundaries and loading condition can be handled. In order to study the influence of mesh refinement and integral area on the result convergence, the models with changing element size and integral areas were investigated. The results obtained by the conservative integral are good agreed with those using curve-fitting technique based on BEM. The accuracy of the results can be improved by mesh refinement. In addition, the results from the area near the singular point are better than the results from the far field. Next, the models with various lengths and difference material properties are investigated to study stress singularity characteristic in three-dimensional dissimilar material joints. The results for the model with various lengths show that the intensity of singularity, K, increases when L_2/L_1 increases. That means the intensity of stresses at the corner can reduce by changing shape of the model to be thinner. And then, the results for the models with various material combinations show that the dimensionless intensities of singularity, k, is related to L_2/L_1 in power law, and the intensity of the singularity decreases when Young's modulus of material 2 decreases.

In conclusion, this study shows that the enriched FEM and the conservative integral are effective methods for calculating the intensity of singularity in two-dimensional and three-dimensional dissimilar material joints, respectively. Influences of material combination, model geometry and loading condition on the intensity of singularity in dissimilar material joints are studied in details. The results obtained in this work are useful for selection of the material combination and joint geometry to reduce stress singularity.